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Editorial

Mechanical, Corrosive, and Tribological Degradation of Metal Coatings and Modified Metallic Surfaces

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Mechanical, corrosive, and tribological degradation of metal and metal coatings is just one of the challenges faced by numerous industries. The industries which are most commonly affected by the degradation of the material are the tool industry, medicine, the electronic industry, the transport industry, aeronautics, the mining industry, and the energy sector. For this reason, it is important to constantly adapt and search for the further improvement of metallic surfaces and metal coatings.

Mechanical degradation of metals normally occurs under the influence of various external forces such as tension, compression, and shear that are commonly present during various material processing and applications such as grinding, agitation, and extrusion [1].

Corrosive degradation of the metal involves redox reactions, under which the metal ions are lost by the dissolution at the anode (oxidation) in a corrosive environment [2]. Despite the fact that different types of coatings are used for improvement of corrosion resistance for metallic surfaces, there is still room for improvement that is needed for specific application that require various mechanical and corrosive properties simultaneously. Furthermore, the development of new coatings is ongoing, due to the continuous learning of corrosion–coating interactions and the necessity of optimizing the coating technology for the development of more affordable and sustainable coatings.

Tribological degradation, which is mostly bound to the contact interaction of two materials and their loss in mass due to this interaction, is another form of material degradation that is the most commonly considered aspect in applications with moveable parts. In this case, wear (abrasion and adhesion) and galling of components are the major forms of mechanically based degradation, which induce the deformation and removal of interacting materials [3]. Additionally, when oxidative or corrosive conditions are present, the mechanical wear is enhanced by the corrosion reactions, leading to tribocorrosion that usually causes rapid degradation of the material [4].

To counter the above degradation effects, coatings are most commonly applied as a laminar layer of certain material that covers the base material with aim of protecting it in order to sustain its properties, with the added properties of the coating layer under specific conditions. When choosing the right coating for the selected material, several parameters have to be considered: thickness, roughness, defects on the coating, tensile strength, elongation, resistivity, structure, residual stresses, adhesion, hardness, ductility, electrical properties, magnetic properties, and anti-corrosion resistivity. All of these coating properties are important as they have impact on its final properties and applicability under the targeted environment and conditions [5,6]. Metallic coatings can consist of metals (Ni, Zn, Cr etc.), metal composites (usually deposited on expensive materials), or metal alloys

(Pb-Sn-Cu, Ni-Cr-Al-Y etc.). Coatings can be produced by immersion, spray, crystallization, cladding, and galvanization [5,6].

Modification of the metallic surface is another possibility to enhance the surface of the material to different degradation conditions, at which the modified base material is used as the surface protector. In contrast to coatings, this technique allows higher compatibility and integrability of the surface to the bulk, reducing the possibility of delamination, decohesion, and interface-weakening between the surface and bulk of the material [5,6].

The surface modification and coating development can be done by laser technology [7], electron beam technology [8], ion implantation [9,10], glow discharge technology [11], chemical vapor deposition (CVD) [11,12], and vacuum deposition by physical vapor deposition (PVD) [13]. Laser technique can also be used for formation of thin and hard coatings, where coatings can be formed by the fusion of alloying elements with gas method (CVD and PVD), by the pure vapor deposition method (PVD), or by pyrolytic and photochemical formation, and even by chemical methods (LCVD) [13]. Electron beam deposition (also known as EBPVD) is a method of using electron beams in a vacuum to irradiate evaporated material, so that it can form as a thin film on the base material. Ion implantation technique is used for the modification of the surface structure in the superficial layer, which can change the surface in a physical as well as chemical fashion through direct ion implantation or plasma ion integration [14]. Glow discharge technology covers methods such as carburizing, carbonitriding, nitriding, and sulfonitriding, as well as boriding and siliciding [11]. Glow discharge methods are characterized by the use of non-equilibrium, low temperature, and non-isothermal plasma, which is formed as a result of the continuous drawing of energy from the electric field [11]. CVD and plasma-assisted CVD (PACVD) are treatments whereby the deposition of a layer from the gas phase is formed through additional participation of a chemical reaction or series of them. In the majority of cases, these techniques are applied for the development of anti-abrasion and anti-corrosion layers [13]. PVD is a technique of surface engineering during which the coating material is evaporated and condensed on the target material in a vacuum. With prior treatment of the substrate material, the fusion and compatibility of the coating can be significantly enhanced [13].

In the last few years, with the increased demands on reduction of material consumption, recycling of the material, environmental safety, improvement of the material performance and life cycle, and last but not least, cost saving of the production, it has become a further necessity to develop new alternatives to enhance both the surface as well as the bulk of materials in a single processing procedure [15]. As such, development and optimization of heat treatment procedures has obtained increasing emphasis in recent research. One of the possible alternatives, which is also a green technology, is cryogenic treatment, during which the material is exposed to cryogenic temperatures (sub-zero temperatures) [16,17]. The advantage of cryogenic treatment in comparison to coatings and surface modification techniques is that it can change the properties of the material from surface to core, whereas coatings and modification of metallic material are confined only to the properties of the surface layer. As a result, the latter only works as long as the coating/modified surface remains stable in protecting the material core, whereas heat treatment-based techniques can omit this dependency.

To summarize, combining different heat treatment methods and surface engineering methods (coatings and modification of the surface layer) is the best way to improve materials' properties and provide the most optimal method for improving materials' resistance and performance.

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